Teaching Control Engineering Courses: MATLAB & Simulink to Improve Student Engagement & Understanding

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Contents

- **Control courses** in Engineering curricula
- From in-person to remote teaching
- **Engaging students**
  - MATLAB & Simulink to improve understanding
  - Bridging theory & practice: examples
- Is a recipe for success?
- Final remarks

Digital Control Systems Syllabus

- **3rd year BSc Informatics & Elecronics Engineering**
- **Knowledge**
  - **Digital Control Systems theory**: models & tools in discrete-time
- **Abilities**
  - **Analysis & design of digital controllers** for linear systems
  - Direct **digital design techniques** & mappings from continuous time to discrete time (MATLAB + Simulink)

Teaching Strategy

- **Planned** (until February 2020)
  - Blended learning
    - Online educational materials (pre-recorded videos)
    - Laboratory experiences & discussion (in person)
- ✓ **Acual** (from March 2020)
  - Asyncronous & pre-recorded videos (YouTube)
    - Theory lectures (< 30')
    - Laboratory experiences & tutorials (guided hands-on, < 90')
  - Teacher-Student Interactions
    - By email (98%, requested by students)

Engaging Students

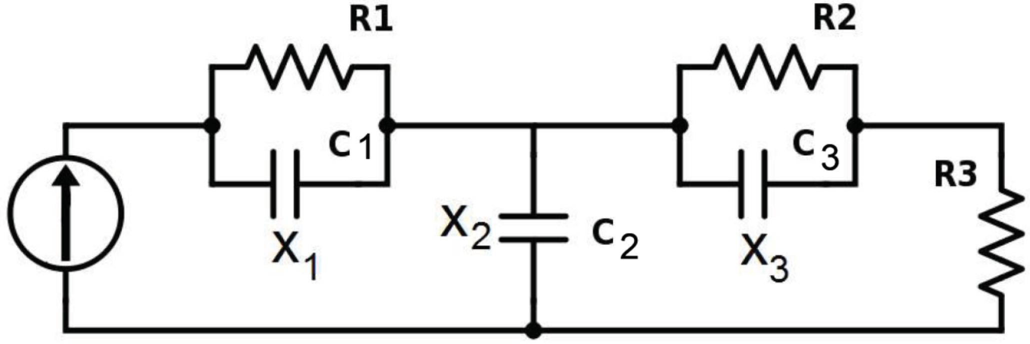
Engaging Students (cont'd)

- Main point (to me)
  - **Best selection of platforms & technologies**
  - Very first experience of remote teaching!
- Attract student attention

1. ***Learning by doing***
   - bridging theory & practice
2. ***Real & realistic examples***
   - Cooperations with industries, technology transfer projects
3. ***Semi-automated design tools (GUI)***
   - MATLAB -> Simulink

1. Learning by Doing

- **Computation of the transfer function**



$$C_1\dot{x}_1 + \frac{x_1}{R_1} = u$$

$$C_2\dot{x}_2 + \frac{x_2 - x_3}{R_3} = u$$

$$C_3\dot{x}_3 - \frac{x_2 - x_3}{R_3} + \frac{x_3}{R_2} = 0$$

1. Learning by Doing (cont'd)

➢Symbolic Toolbox

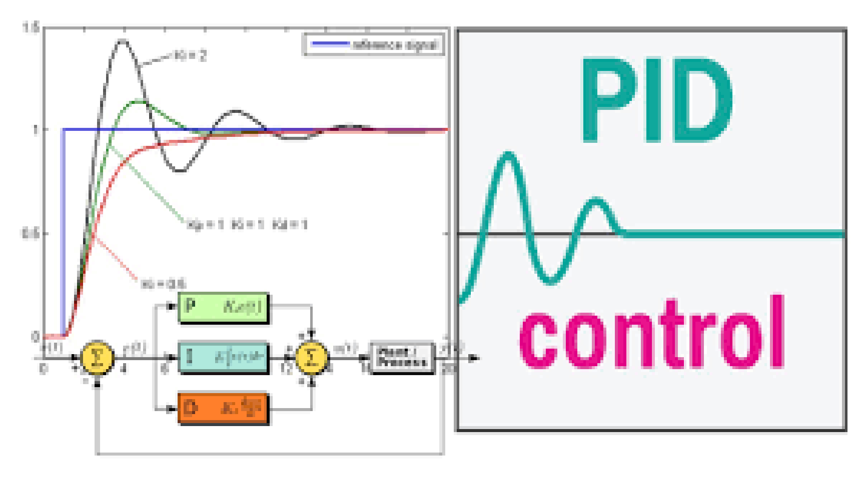
```
>> syms x1 x2 x3 x1dot x2dot x3dot u C1 C2 C3 R1 R2 R3
>> eqns = [C1*x1dot + x1/R1 == u;
           C2*x2dot + (x2-x3)/R3 == u;
           C3*x3dot - (x2-x3)/R3 + x3/R2 == 0];
>> [x1dot,x2dot,x3dot]=solve(eqns,[x1dot;x2dot;x3dot]);
>> [A,Bu]=equationsToMatrix([x1dot;x2dot;x3dot],[x1;x2;x3]);
>> B=-Bu/u;
>> C=[0 0 1];
>> D=0;
```

Parameters : $C_1 = C_2 = C_3 = 0{,}1$; $R_1 = R_2 = 10$; $R_3 = 5$;

```
>> C1=0.1; C2=0.1; C3=0.1; R1 = 10; R2 = 10; R3 = 5;
>> A=double(subs(A));
>> B=double(subs(B));
>> sys=ss(A,B,C,0)
```

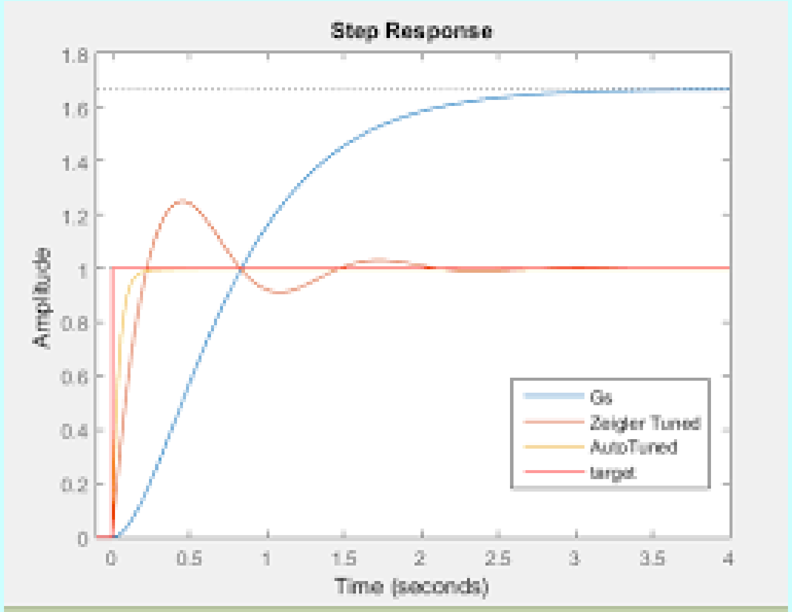
2. Real Application

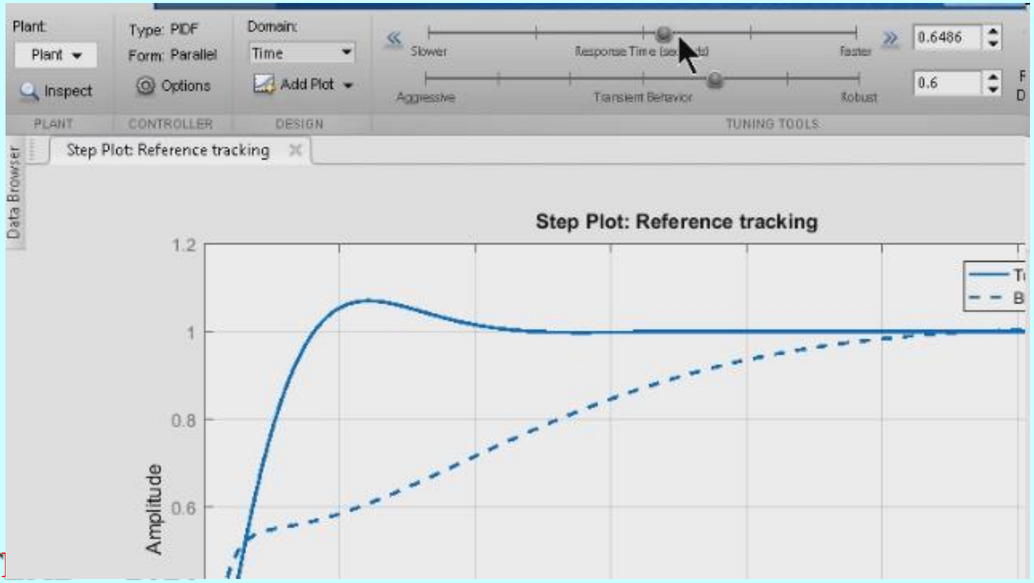
- ➢ Example: PID control
- ➢ **Jeep Wrangler Engine**
- ✓ Technology transfer project
- ✓ Theory/Practice
  - ➢ Ziegler-Nichols
  - ➢ Simulink Control Design
  - ➢ PID auto-tuning



3. Semi-Automated Design

- ➢ Example: PID controllers
- ✓ Design approach
  - GUI/auto-tuning
- ✓ To practice
  - ➢ PID parameters
  - ➢ Simulink block
  - ➢ Comparison Z-N & autotuning





3. Semi-Automated Design (cont'd)

- **Automated design**
- Lag network
- **Inversion formulas**
- Required attenuation *M** at the frequency ω*
- ✓ Given M_f
- Phase variation φ*

$$F(\tau_1,\tau_2) = M^* e^{j\varphi^*} = \frac{1+j\tau_1\omega^*}{1+j\tau_2\omega*}$$

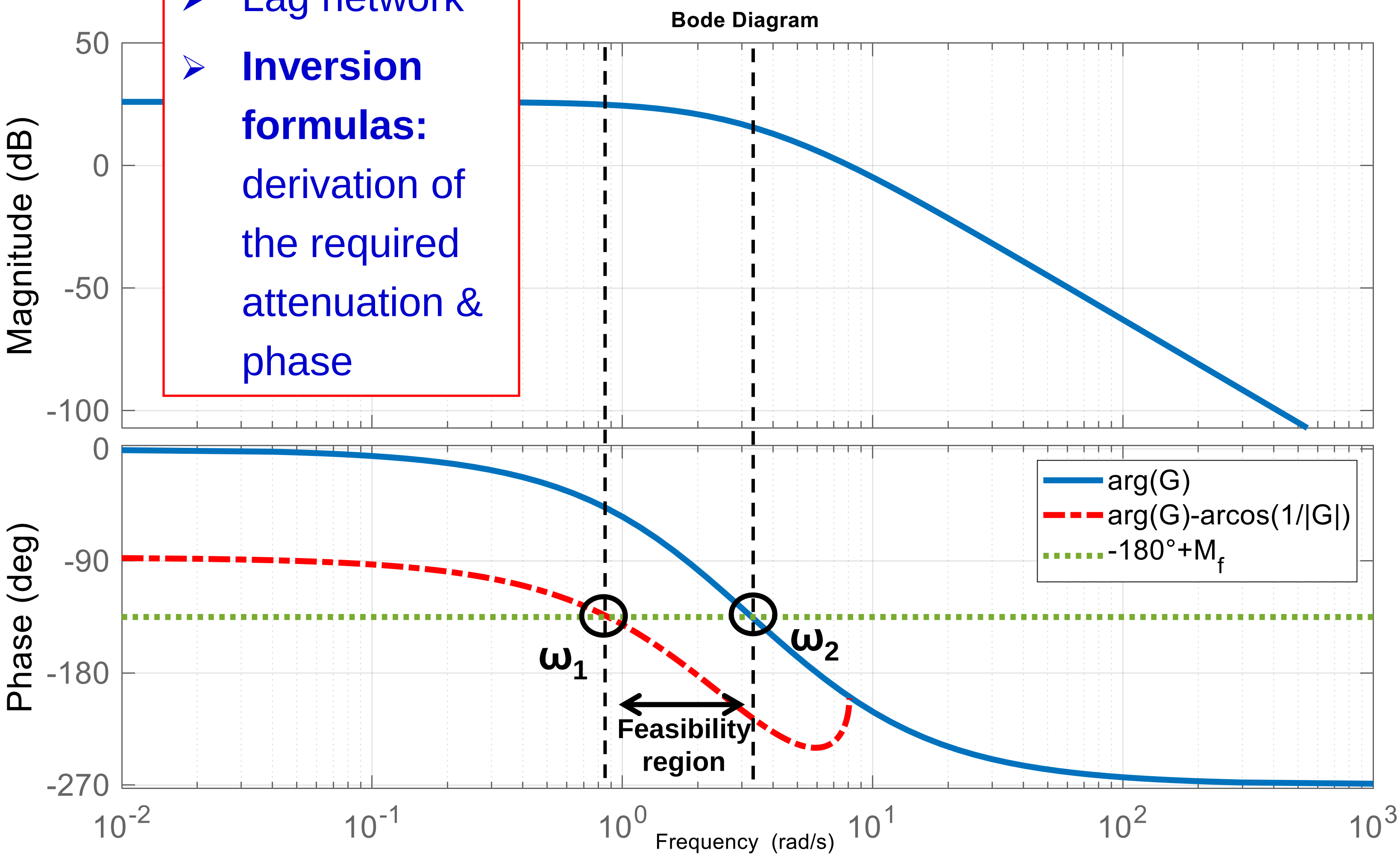
$$\tau_1 = \frac{M^* - \cos\varphi^*}{\omega^* \sin\varphi^*}$$

$$\tau_2 = \frac{\cos\varphi^* - \frac{1}{M^*}}{\omega^* \sin\varphi^*}$$

$$\boldsymbol{\varphi^*} = -180° + \mathbf{M_F} - \arg[G(j\omega^*)]$$

3. Semi-Automated Design (cont'd)

- Lag network
- **Inversion formulas:** derivation of the required attenuation & phase



$$R(\omega) = \arg[G(j\omega)] - \arccos(1/|G(j\,\omega)|)$$

A Recipe for Success?

Quality Assessment

- ✓ **Exam** (online, this year)
  - Multiple choice questions (theory)
  - Simulink project (practice)
- ✓ **Student surveys**
  - Course evaluation questionnaire
  - 12 questions (teacher quality, effectiveness & interest, course structure, course contents, hands on & labs)
  - 2 more questions on online methods (this year)
- ✓ **Exam scores**
  - average & std. dev. values + failure rates
- ➢ **Better results than 2019 (in-person)!**

Concluding Remaks & Further Works

- **Student engagement**
  - Theory & practice integration
  - ✓ Matlab & Simulink tools
- **Teaching & learning strategies improvement**
  - i. Matlab Live Scripts (Simulink?)
  - ii. Matlab Grader (in Moodle, June 2020)
    - Google forms & Classroom (most frequently used)
  - iii. Interactive video quizzing (theory, knowledge)

Thanks You for Listening